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CONCERNING A FILING UNDER 35 U.S.C. 371**

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TITLE OF INVENTION

HYDROCRACKING PROCESS USING BULK GROUP VIII/GROUP VIB CATALYSTS

APPLICANT(S) FOR DO/EO/US

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Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is the **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is the **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ has been communicated by the International Bureau.
 - c. ☒ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application number PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1 821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English translation of the international application under 35 U.S.C. 154(d)(4)
20. ☒ Other items or information.
 - **THIS APPLICATION IS A CONTINUATION-IN-PART OF U.S. SERIAL NO. 09/231.156 FILED JANUARY 15, 1999, WHICH IS A CONTINUATION IN PART OF U.S. SERIAL NO. 08/900,389 FILED JULY 15, 1997.**
 - **THE U.S. PATENT OFFICE ACTED AS RO, ISA AND IPEA.**

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HYDROCRACKING PROCESS USING BULK GROUP VIII/GROUP VIB CATALYSTS

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of U.S. Ser. No. 09/231,156 filed January 15, 1999 which is a continuation-in-part of U.S. Ser. No. 08/900,389 filed July 15, 1997.

FIELD OF THE INVENTION

This invention relates to the hydroprocessing of petroleum and chemical feedstocks using bulk Group VIII/Group VIB catalysts. Preferred catalysts include those comprised of Ni-Mo-W.

BACKGROUND OF THE INVENTION

As the supply of low sulfur, low nitrogen crudes decrease, refineries are processing crudes with greater sulfur and nitrogen contents at the same time that environmental regulations are mandating lower levels of these heteroatoms in products. Consequently, a need exists for increasingly efficient desulfurization and denitrogenation catalysts.

In one approach, a family of compounds, related to hydrotalcites, e.g., ammonium nickel molybdates, has been prepared. Whereas X-ray diffraction analysis has shown that hydrotalcites are composed of layered phases with positively charged sheets and exchangeable anions located in the galleries between the sheets, the related ammonium nickel molybdate phase has molybdate anions in interlayer galleries bonded to nickel oxyhydroxide sheets. See, for example, Levin, D., Soled, S. L., and Ying, J. Y., Crystal Structure of an Ammonium Nickel Molybdate prepared by Chemical Precipitation, Inorganic Chemistry, Vol. 35, No. 14, p. 4191-4197 (1996). The preparation of such materials also has been reported by Teichner and Astier, Appl. Catal. 72, 321-29

(1991); Ann. Chim. Fr. 12, 337-43 (1987), and C. R. Acad. Sci. 304 (II), #11, 563-6 (1987) and Mazzocchia, Solid State Ionics, 63-65 (1993) 731-35.

Now, when molybdenum is partially substituted for by tungsten, an amorphous phase is produced which upon decomposition and, preferably, sulfidation, provides enhanced hydrodenitrogenation (HDN) catalyst activity relative to the unsubstituted (Ni-Mo) phase.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided a process for hydroprocessing a hydrocarbon feedstock, which process comprises contacting said feedstock, at hydroprocessing conditions, with a bulk catalyst comprised of at least one Group VIII metal and two Group VIB metals, which catalyst comprises a bulk metal catalyst containing non-noble Group VIII metal molybdate in which at least a portion but less than all of the molybdenum is replaced by tungsten. The hydroprocessing process is selected from at least one of hydrodesulfurization, hydrodenitrogenation, hydrodemetallation, hydrodearomatization, hydroisomerization, hydrodewaxing, hydrotreating, hydrofining and hydrocracking.

In one embodiment of the invention there is provided process for preparing lubricating oil basestocks which comprises:

(a) contacting a hydrocarbon feedstock feedstock derived from at least one of thermal treatment, catalytic treatment, extraction, dewaxing or fractionation of a petroleum crude or fraction thereof, shale oil, tar sands or synthetic crude with a bulk metal catalyst under hydrocracking conditions, said catalyst comprising non-noble Group VIII metal molybdate in which at least a portion but less than all of molybdenum is replaced by tungsten; and

(b) fractionating hydrocracked feedstock to produce a distillate lubricating oil fraction.

Another embodiment of the invention relates to a process for producing lubricating oil basestocks which comprises:

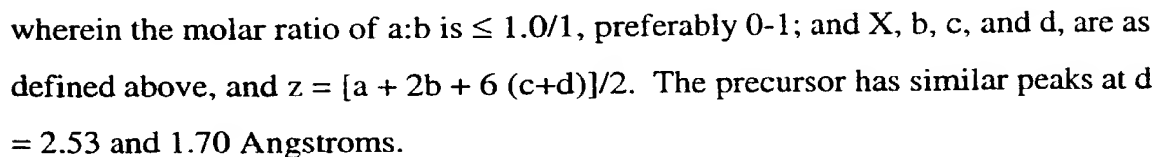
(a) feeding a hydrocarbon feedstock derived from at least one of thermal treatment, catalytic treatment, extraction, dewaxing or fractionation of a petroleum crude or fraction thereof, shale oil, tar sands or synthetic crude, to a first hydrocracking zone containing a hydrocracking catalyst wherein said hydrocracking catalyst is a bulk metal catalyst comprising non-noble Group VIII metal molybdate in which at least a portion but less than all of molybdenum is replaced by tungsten to produce a hydrotreated feedstock;

(b) hydrocracking the feedstock under hydrocracking conditions to produce a hydrocracked;

(c) conducting the hydrocracked feed to a second hydrocracking zone containing a second hydrocracking catalyst and hydrocracking the first hydrocracked feed under hydrocracking conditions to produce a second hydrocracked feed; and

(d) fractionating the second hydrocracked feed to produce a distillate lubricating oil fraction.

In another preferred embodiment of the present invention the catalyst composition is prepared by a process which comprises contacting at least one Group VIII non-noble metal component with the Group VIB metal component in



The catalyst composition according to the invention can be used in virtually all hydroprocessing processes to treat a plurality of feeds under wide-ranging reaction conditions such as temperatures of from 200 to 450°C, hydrogen pressures of from 5 to 300 bar, liquid hourly space velocities of from 0.05 to 10

h^{-1} and hydrogen treat gas rates of from 35.6 to 1780 m^3/m^3 (200 to 10000 SCF/B). The term "hydroprocessing" encompasses all processes in which a hydrocarbon feed is reacted with hydrogen at the temperatures and pressures noted above, and include hydrogenation, hydrotreating, hydrodesulfurization, hydrodenitrogenation, hydrodemetallation, hydrodearomatization, hydroisomerization, hydrodewaxing, and hydrocracking including selective hydrocracking. Depending on the type of hydroprocessing and the reaction conditions, the products of hydroprocessing may show improved viscosities, viscosity indices, saturates content, low temperature properties, volatilities and depolarization. Feeds for hydroprocessing include reduced crudes, hydrocrackates, raffinates, hydrotreated oils, atmospheric and vacuum gas oils, coker gas oils, atmospheric and vacuum resids, deasphalted oils, dewaxed oils, slack waxes, Fischer-Tropsch waxes and mixtures thereof. It is to be understood that hydroprocessing of the present invention can be practiced in one or more reaction zones and can be practiced in either countercurrent flow or cocurrent flow mode. By countercurrent flow mode we mean a process mode wherein the feedstream flows countercurrent to the flow of hydrogen-containing treat gas.

The catalyst composition of the invention is particularly suitable for hydrotreating the hydrocarbon feeds suitable for hydroprocessing as noted above. Examples of hydrotreating include hydrogenation of unsaturates, hydrodesulfurization, hydrodenitrogenation, hydrodearomatization and mild hydrocracking. Conventional hydrotreating conditions include temperatures of from 250° to 450°C, hydrogen pressures of from 5 to 250 bar, liquid hourly space velocities of from 0.1 to 10 h^{-1} , and hydrogen treat gas rates of from 90 to 1780 m^3/m^3 (500 to 10000 SCF/B). The hydrotreating processes using the catalyst according to the invention may be particularly suitable for making lubricating oil basestocks meeting Group II or Group III base oil requirements.

The hydrocarbon feedstocks which are typically subjected to hydrocracking herein will typically boil at a temperature above 150°C. The feedstocks can contain a substantial amount of nitrogen, e.g. at least 10 wppm nitrogen, and even greater than 500 wppm, in the form of organic nitrogen compounds. The feeds can also have a significant sulfur content, ranging from about 0.1 wt.% to 3 wt.%, or higher. If desired, the feeds can be treated in a known or conventional manner to reduce the sulfur and/or nitrogen content thereof. Examples of hydrocarbon feedstocks are those derived from at least one of thermal treatment, catalytic treatment, extraction, dewaxing or fractionation of a petroleum crude or fraction thereof, shale oil, tar sands or synthetic crude.

In the present hydrocarbon process, a feedstock is subjected to hydrocracking in a first zone in the presence of the bulk metal catalyst of the invention. Hydrocracking conditions include temperatures of from 300 to 480 °C, hydrogen pressures of from 1000 to 3500 psig (6995 to 24234 KPa), liquid hourly space velocities of from 0.2 to 4.0 and hydrogen treat gas rates of from 1000 to 15000 scf/B (178 to 2670 m³/m³). The product from the first hydrocracking zone may be fractionated to isolate a lubricating oil fraction.

The product, i.e., hydrocrackate, from the first hydrocracking zone may be further hydrocracked in a second hydrocracking zone. The hydrocracking conditions in the second hydrocracking zone are the same as those in the first hydrocracking zone. The hydrocracking catalyst in the second hydrocracking zone may be the bulk metal catalyst of the first hydrocracking zone, crystalline or amorphous metal oxides or mixtures thereof. Preferred crystalline metal oxides are molecular sieves including zeolites and silicoaluminophosphates. Preferred zeolites include zeolite X and Y which may be supported on a refractory metal oxide. Preferred amorphous metal oxides include silica-alumina.

The hydrocrackate from either the first or second hydrocracking zones may be further processed by fractionation to obtain a distillate lubricating oil fraction. This distillate fraction may then be solvent extracted with conventional solvents such as furfural, phenol or N-methyl-2-pyrrolidone (NMP) under solvent extraction conditions. Raffinate from solvent extraction may then be further processed by a combination of dewaxing and/or hydrofinishing. Dewaxing may be by solvent or catalytic dewaxing. Preferred solvent dewaxing utilizes conventional solvents including ketones such as methyl ethyl ketone, methyl isobutyl ketone or mixtures thereof. Catalytic dewaxing is by 8, 10 or 12 ring molecular sieves, preferably 10 ring molecular sieves under catalytic dewaxing conditions. Preferred 10 ring molecular sieves are zeolites or SAPOs.

Preferred zeolites include ZSM-5, ZSM-22, ZSM-23, ZSM-35, ZSM-48 and ZSM-57. Preferred SAPOs include SAPO-11 and SAPO-41. In the alternative, the distillate fraction may be catalytically dewaxed without an intervening solvent extraction step.

The solvent or catalytically dewaxed product may then be hydrofinished in a hydrofinishing zone under hydrofinishing conditions. Hydrofinishing conditions include a temperature of from 200 to 370 °C, pressure of from 150 to 3000 psig (1136 to 20786 kPa), liquid hourly space velocity of from 0.2 to 5.0 and a hydrogen treat rate of from 100 to 5000 scf/B (17.8 to 890 m³/m³). Hydrofinishing catalysts may be the bulk metal catalyst used in the hydrocracking zone or may be conventional hydrofinishing catalysts such as those containing at least one Group VIII metal on a refractory metal oxide support which may be promoted. The Group VIII metal may be combined with a Group VIB metal. If the Group VIII metal is a non-noble metal, it is preferably combined with a Group VIB metal.

Products from the process of the invention include Group II and Group III lubricating oil basestocks. Group II basestocks have a saturates content of at least 90%, a sulfur content less than 0.03 wt.% and a VI less than 120. Group III basestocks have a saturates content of at least 90%, a sulfur content less than 0.03 wt.% and a VI greater than 120.

For purposes of the present invention where it is desirable to produce a lube basestock the feed can be a wide variety of wax-containing feedstocks including feeds derived from crude oils, shale oils and tar sands as well as synthetic feeds such as those derived from the Fischer-Tropsch process. Typical wax-containing feedstocks for the preparation of lubricating base oils have initial boiling points of about 315° C or higher, and include feeds such as reduced crudes, hydrocrackates, raffinates, hydrotreated oils, atmospheric gas oils,

Generally, the contacting of the metal components in the presence of the protic liquid comprises mixing the metal components and subsequently reacting the resulting mixture. It is essential to the solid route that at least one metal components is added at least partly in the solid state during the mixing step and

If during the mixing step at least one metal component is added at least partly in the solid state and at least one metal component is added in the solute state, the following process alternatives can be applied: it is possible to first prepare a suspension of a metal component in the protic liquid and to add simultaneously, or one after the other, solutions and/or further suspensions comprising dissolved and/or suspended metal components in the protic liquid. It is also possible to first combine solutions either simultaneously or one after the other and to subsequently add further suspensions and optionally solutions either simultaneously or one after the other. If during the mixing step, each metal

components are added in the solute state. For instance, one metal component is added at least partly in the solid state and two metal components are added in the solute state. In another embodiment, two metal components are added at least partly in the solid state and one metal component is added in the solute state. In still another embodiment, three or more metal components are added at least partly in the solid state and no further metal components are added in the solute state. Generally, the number of metal components which are added at least partly in the solid state and which are added in the solute state is not critical to the this invention.

It will be clear that it is, e.g., not suitable to prepare first a solution comprising all metal components necessary for the preparation of a certain catalyst composition and to subsequently coprecipitate these components. Nor is it suitable for the process for the this invention to add metal components at least partly in the solid state and to choose the process conditions, such as temperature, pH or amount of protic liquid in such a way, that all added metal components are present at least at some stage completely in the solute state. On the contrary, as has been set out above, for the solid route, at least the metal of one of the metal components that are added at least partly in the solid state must remain in at least partly the solid state during the entire process of this invention.

Preferably, at least 1 wt.%, even more preferably at least 10 wt.% and most preferably at least 15 wt.% of the metal components are in the solid state during mixing, based on the total weight of all added metal components, i.e., of all metal components employed initially in the solid route, calculated as metal oxides. When it is desired to obtain a high yield, i.e., a high amount of the bulk catalyst composition, the use of metal components of which a high amount remains in the solid state during contacting is recommended. As in this case, low amounts of metal components remain solved in the mother liquid, the amount of

metal components ending up in the wastewater during the subsequent solid-liquid separation is decreased.

If the metals which are added at least partly in the solid state are added as a suspension, the amount of solid metals in this suspension can be determined by filtration of the suspension at the conditions which are applied during the mixing step (temperature, pH, pressure, amount of liquid) in such a way that all solid material contained in the suspension is collected as solid filter cake. From the weight of the solid and dried filter cake, the weight of the solid metals can be determined by standard techniques. If several suspensions are applied, the weight of the solid metal components contained in these suspensions must be added to each other to give the total amount of solid metal components, calculated as metal oxides. Of course, if apart from solid metal components further solid components such as a solid binder are present in the filter cake, the weight of this solid and dried binder must be subtracted from the weight of the metal components in the solid and dried filter cake. In this case, standard techniques such as atomic absorption spectroscopy (AAS), XRF, wet chemical analysis, or ICP can determine the amount of solid metals in the filter cake.

If the metal component, which is added at least partly in the solid state, is added in the wetted or dry state, a filtration generally is not possible. In this case, the weight of the solid metal component is considered equal to the weight of the corresponding initially employed metal component. The total weight of all metal components is the amount of all metals that are initially employed as metal components, calculated as metal oxides.

It has been found that the morphology and texture of the metal component, which remains at least partly in the solid state during contacting, may determine the morphology and texture of the bulk catalyst composition.

Consequently, e.g., by applying metal component particles with a certain morphology and texture, the morphology and texture of the resulting bulk catalyst particles can be controlled. "Morphology and texture" in the sense of the present invention refer to pore volume, pore size distribution, surface area, particle form, and particle size.

To obtain a bulk catalyst composition with high catalytic activity, it is therefore preferred that the metal components, which are at least partly in the solid state during contacting, are porous metal components. It is desired that the total pore volume and pore size distribution of these metal components is approximately the same as those of conventional hydrotreating catalysts. Conventional hydrotreating catalysts generally have a pore volume of 0.05 - 5 ml/g, preferably of 0.1 - 4 ml/g, more preferably of 0.1 - 3 ml/g and most preferably of 0.1 - 2 ml/g determined by nitrogen adsorption. Pores with a diameter smaller than 1 nm are generally not present in conventional hydrotreating catalysts. Further, conventional hydrotreating catalysts have generally a surface area of at least 10 m²/g and more preferably of at least 50 m²/g and most preferably of at least 100 m²/g, determined VIB the B.E.T. method. For instance, nickel carbonate can be chosen which has a total pore volume of 0.19 - 0.39 ml/g and preferably of 0.24 - 0.35 ml/g determined by nitrogen adsorption and a surface area of 150 - 400 m²/g and more preferably of 200 - 370 m²/g determined by the B.E.T. method. Furthermore these metal components should have a median particle diameter of at least 50 nm, more preferably at least 100 nm, and preferably not more than 5000 µm and more preferably not more than 3000 µm. Even more preferably, the median particle diameter lies in the range of 0.1 - 50 µm and most preferably in the range of 0.5 - 50 µm. For instance, by choosing a metal component which is added at least partly in the solid state and which has a large median particle diameter, the other

metal components will only react with the outer layer of the large metal component particle. In this case, so-called "core-shell" structured bulk catalyst particles are obtained.

An appropriate morphology and texture of the metal component can either be achieved by applying suitable preformed metal components or by preparing these metal components by the above-described precipitation under such conditions that a suitable morphology and texture is obtained. A proper selection of appropriate precipitation conditions can be made by routine experimentation.

As has been set out above, to retain the morphology and texture of the metal components which are added at least partly in the solid state, it is essential that the metal of the metal component at least partly remains in the solid state during the whole process of this solid route. It is noted again that it is essential that in no case should the amount of solid metals during the process of the solid route becomes zero. The presence of solid metal comprising particles can easily be detected by visual inspection at least if the diameter of the solid particles in which the metals are comprised is larger than the wavelength of visible light. Of course, methods such as quasi-elastic light scattering (QELS) or near forward scattering which are known to the skilled person can also be used to ensure that in no point in time of the process of the solid route, all metals are in the solute state.

Without wishing to be bound by any theory, it is believed that during the process of the solid route, the metal components, which are added during the mixing step at least partly, react with each other. The protic liquid is responsible for the transport of dissolved metal components. Due to this transport, the metal components come into contact with each other and can react. It is believed that this reaction can even take place if all metal components are virtually completely

in the solid state. Due to the presence of the protic liquid, a small fraction of metal components may still dissolve and consequently react as described above. The presence of a protic liquid during the process of the solid route is therefore considered essential. The reaction can be monitored by any conventional technique such as IR spectroscopy, Raman spectroscopy, or by monitoring the pH of the reaction mixture.

In one preferred embodiment of the solid route, during mixing not all metal components are added completely in the solid state. Preferably, at least 0.1 wt.%, more preferably at least 0.5 wt.% and still more preferably at least 1 wt.% of the metal components initially employed in the solid route are added as a solution during the mixing step, calculated as metal oxides. In this way, proper contacting of the metal components is ensured.

The protic liquid to be applied in the solid or solution route of this invention for preparing catalyst can be any protic liquid. Examples include water, carboxylic acids, and alcohols such as methanol or ethanol.- Preferably, a liquid comprising water such as mixtures of an alcohol and water and more preferably water is used as protic liquid in this solid route. Also different protic liquids can be applied simultaneously in the solid route. For instance, it is possible to add a suspension of a metal component in ethanol to an aqueous solution of another metal component. In some cases, a metal component can be used which dissolves in its own crystal water. The crystal water serves as protic liquid in this case.

The molar ratio of Group VIB to Group VIII non-noble metals applied in the solid route ranges generally from 10:1 - 1:10 and preferably from 3:1 - 1:3. In the case of core-shell structured particles, these ratios may lie outside the above ranges. If more than one Group VIB metal is used, the ratio of the

different Group VIB metals is generally not critical. The same holds when more than one Group VIII non-noble metal is used. In the case where molybdenum and tungsten are applied as Group VIB metals, the molybdenum:tungsten ratio preferably lies in the range of 9:1 - 1:9.

The Group VIB metal generally comprises chromium, molybdenum, tungsten, or mixtures thereof. Suitable Group VIII non-noble metals are, e.g., iron, cobalt, nickel, or mixtures thereof. Preferably, a combination of metal components comprising nickel, molybdenum and tungsten or nickel, cobalt, molybdenum and tungsten is applied in the process of the solid route. If the protic liquid is water, suitable nickel components which are at least partly in the solid state during contacting comprise water-insoluble nickel components such as nickel carbonate, nickel hydroxide, nickel phosphate, nickel phosphite, nickel formate, nickel sulfide, nickel molybdate, nickel tungstate, nickel oxide, nickel alloys such as nickel-molybdenum alloys, Raney nickel, or mixtures thereof. Suitable molybdenum components, which are at least partly in the solid state during contacting, comprise water-insoluble molybdenum components such as molybdenum (di- and tri) oxide, molybdenum carbide, molybdenum nitride, aluminum molybdate, molybdic acid (e.g. H_2MoO_4), molybdenum sulfide, or mixtures thereof. Finally, suitable tungsten components which are at least partly in the solid state during contacting comprise tungsten di- and trioxide, tungsten sulfide (WS_2 and WS_3), tungsten carbide, tungstic acid (e.g., $\text{H}_2\text{WO}_4 \cdot \text{H}_2\text{O}$, $\text{H}_2\text{W}_4\text{O}_{13} \cdot 9\text{H}_2\text{O}$), tungsten nitride, aluminum tungstate (also meta-, or polytungstate) or mixtures thereof. These components are generally commercially available or can be prepared by, e.g., precipitation. e.g., nickel carbonate can be prepared from a nickel chloride, sulfate, or nitrate solution by adding an appropriate amount of sodium carbonate. It is generally known to the skilled person to choose the precipitation conditions in such a way as to obtain the desired morphology and texture.

In general, metal components, which mainly contain C, O. and/or H beside the metal, are preferred because they are less detrimental to the environment. Nickel carbonate is a preferred metal component to be added at least partly in the solid state because when nickel carbonate is applied, CO₂ evolves and positively influences the pH of the reaction mixture. Further, due to the transformation of carbonate into CO₂, the carbonate does not end up in the wastewater.

Preferred nickel components which are added in the solute state are water-soluble nickel components, e.g., nickel nitrate, nickel sulfate, nickel acetate, nickel chloride, or mixtures thereof. Preferred molybdenum and tungsten components which are added in the solute state are water-soluble molybdenum and tungsten components such as alkali metal or ammonium molybdate (also peroxo-, di-, tri-, tetra-, hepta-, octa-, or tetradecamolybdate), Mo-P heteropolyanion compounds, Wo-Si heteropolyanion compounds, W-P heteropolyanion compounds, W-Si heteropolyanion compounds, Ni-Mo-W heteropolyanion compounds, Co-Mo-W heteropolyanion compounds, alkali metal or ammonium tungstates (also meta-, para-, hexa-, or polytungstate), or mixtures thereof.

Preferred combinations of metal components are nickel carbonate, tungstic acid and molybdenum oxide. Another preferred combination is nickel carbonate, ammonium dimolybdate and ammonium metatungstate. It is within the scope of the skilled person to select further suitable combinations of metal components. It must be noted that nickel carbonate always comprises a certain amount of hydroxy-groups. It is preferred that the amount of hydroxy-groups present in the nickel carbonate be high.

In the following, preferred process conditions during the mixing and subsequent reaction step shall be described:

a) Mixing step:

The process conditions during the mixing step are generally not critical. It is, e.g., possible to add all components at ambient temperature at their natural pH (if a suspension or solution is applied). Generally, it is of course preferred to keep the temperature below the boiling point of the protic liquid, i.e., 100°C in the case of water to ensure easy handling of the components during the mixing step. However, if desired also temperatures above the boiling point of the protic liquid or different pH values can be applied. If the reaction step is carried out at increased temperatures, the suspensions and solutions which are added during the mixing step are generally preheated to an increased temperature which can be equal to the reaction temperature.

b) Reaction step:

After all metal components have been mixed, they are generally agitated at a certain temperature for a certain period of time to allow the reaction to take place. The reaction temperature preferably is in the range of 0° - 300°C, more preferably 50° - 300°C, even more preferably 70° - 200°C and most preferably in the range of 70° - 180°C. If the temperature is below the boiling point of the protic liquid, such as 100°C in the case of water, the process is generally carried out at atmospheric pressure. Above this temperature, the reaction is generally carried out at increased pressure, preferably in an autoclave. Generally, the mixture is kept at its natural pH during the reaction step. The pH is preferably in the range of 0 - 12, more preferably 1 - 10 and even more preferably in the range of 3 - 8. As has been set out above, care must be taken that the pH and the temperature are chosen in such a way that not all the metals are dissolved during the reaction step.

The reaction time generally lies in the range of 1 minute to several days, more preferably 1 minute to 24 hours, and most preferably in the range of 5 minutes to 10 hours. As has been mentioned above, the reaction time depends on the temperature.

Process step (i) according to the solution route

As mentioned above, alternatively to the above-described solid route for step (i), it is also possible to prepare the bulk catalyst composition by a process comprising reacting in a reaction mixture a Group VIII non-noble metal component in solution and a Group VIB metal component in solution to obtain a precipitate. As in the case of the solid route, preferably, one Group VIII non-noble metal component is reacted with two Group VIB metal components. The molar ratio of Group VIB metals to Group VIII non-noble metals applied in the process of the solution route is preferably the same as described for the solid route. Suitable Group VIB and Group VIII non-noble metal components are, e.g., those water-soluble nickel, molybdenum and tungsten components described above for the solid route. Further Group VIII non-noble metal components are, e.g., cobalt or iron components. Further Group VIB metal components are, e.g. chromium components. The metal components can be added to the reaction mixture in solution, suspension or as such. If soluble salts are added as such, they will dissolve in the reaction mixture and subsequently be precipitated.

The reaction mixture is reacted to obtain a precipitate. Precipitation is effected by adding a Group VIII nonnoble metal salt solution at a temperature and pH at which the Group VIII nonnoble metal and the Group VIB metal precipitate, adding a compound which complexes the metals and releases the metals for precipitation upon temperature increase or pH change or adding a Group VIB metal salt solution at a temperature and pH at which the Group VIII

nonnoble metal and Group VIB metal precipitate, changing the temperature, changing the pH, or lowering the amount of the solvent. The precipitate obtained with this process appears to have high catalytic activity. In contrast to the conventional hydroprocessing catalysts, which usually comprise a carrier impregnated with Group VIII non-noble metals and Group VIB metals, said precipitate can be used without a support. Unsupported catalyst compositions are usually referred to as bulk catalysts. Changing the pH can be done by adding base or acid to the reaction mixture, or adding compounds, which decompose upon temperature, increase into hydroxide ions or H^+ ions that respectively increase or decrease the pH. Examples of compounds that decompose upon temperature increase and thereby increase or decrease the pH are urea, nitrites, ammonium cyanate, ammonium hydroxide, and ammonium carbonate.

In an illustrative process according to the solution route, solutions of ammonium salts of a Group VIB metal are made and a solution of a Group VIII non-noble metal nitrate is made. Both solutions are heated to a temperature of approximately 90°C. Ammonium hydroxide is added to the Group VIB metal solution. The Group VIII non-noble metal solution is added to the Group VIB metal solution and direct precipitation of the Group VIB and Group VIII non-noble metal components occurs. This process can also be conducted at lower temperature and/or decreased pressure or higher temperature and/or increased pressure.

In another illustrative process according to the solution route, a Group VIB metal salt, a Group VIII metal salt, and ammonium hydroxide are mixed in solution together and heated so that ammonia is driven off and the pH is lowered to a pH at which precipitation occurs. For instance when nickel, molybdenum, and tungsten components are applied, precipitation typically occurs at a pH below 7.

If the binder material is added during the preparation of the bulk catalyst composition, the following options are available: If, e g., the bulk catalyst composition in step (i) is prepared according to the solid route, the metal components can be added to the binder material either simultaneously or one

subsequently re-wetted prior to shaping. This is especially preferred in the case where the bulk catalyst composition has been prepared via the solution route using nitrate and/or ammonium salts. Moreover, additional binder material can be added subsequent to the preparation of the above bulk catalyst binder composition.

As has been set out above, it is preferred to first prepare the bulk catalyst composition and to subsequently composite the resulting bulk catalyst composition with the binder material. Optionally, the bulk catalyst composition can be subjected to a solid-liquid separation before being composited with the binder material. After solid-liquid separation, optionally, a washing step can be included. Further, it is possible to calcine the bulk catalyst composition after an optional solid liquid separation and drying step and prior to compositing it with the binder material.

In all the above-described process alternatives, the term "compositing the bulk catalyst composition with a binder material" means that the binder material is added to the bulk catalyst composition or vice versa and the resulting composition is mixed.

As has been set out above, the median diameter of the bulk catalyst particles is at least 50 nm, more preferably at least 100 nm, and preferably not more than 5000 μm and more preferably not more than 3000 μm . Even more preferably, the median particle diameter lies in the range of 0.1 - 50 μm and most preferably in the range of 0.5-50 μm .

Binder materials to be applied in the process of the invention may be any materials that are conventionally applied as a binder in hydroprocessing catalysts. Examples include silica, silica-alumina, such as conventional silica-alumina,

If alumina is applied as binder, the surface area preferably lies in the range of 100 - 400 m²/g, and more preferably 150 - 350 m²/g, measured by the B.E.T. method. The pore volume of the alumina is preferably in the range of 0.5 - 1.5 ml/g measured by nitrogen adsorption.

Generally, the binder material to be added in the process of the invention has less catalytic activity than the bulk catalyst composition or no catalytic activity at all. Consequently, by adding a binder material, the activity of the bulk catalyst composition may be reduced. Therefore, the amount of binder material to be added in the process of the invention generally depends on the desired activity of the final catalyst composition. Binder amounts from 0 - 95 wt.% of the total composition can be suitable, depending on the envisaged catalytic application. However, to take advantage of the resulting unusual high activity of the composition of the present invention, binder amounts to be added are generally in the range of 0.5 - 75 wt.% of the total composition.

If in the process of the invention, a binder material is used, the resulting catalyst composition comprises the bulk catalyst particles obtained in step (i) imbedded in the binder material. In other words, during the process of the invention, the bulk catalyst particles generally do not disintegrate but normally, the morphology of the bulk catalyst particles is essentially maintained in the resulting catalyst composition.

Process step (iii)

The catalyst composition resulting from the above-described process alternatives can be directly shaped. Shaping comprises extrusion, pelletizing, beading, and/or spray drying. It must be noted that if the catalyst composition is to be applied in slurry type reactors, fluidized beds, moving beds, expanded beds, or ebullating beds, spray drying or beading is generally applied for fixed bed applications, generally, the catalyst composition is extruded, pelletized and/or beaded. In the latter case, prior to or during the shaping step, any additives that are conventionally used to facilitate shaping can be added. These additives may comprise aluminum stearate, surfactants, graphite or mixtures thereof. These

additives can be added at any stage prior to the shaping step. Further, when alumina is used as a binder, it may be desirable to add acids prior to the shaping step such as nitric acid to increase the mechanical strength of the extrudates.

It is preferred that a binder material is added prior to the shaping step. Further, it is preferred that the shaping step is carried out in the presence of a liquid, such as water. Preferably, the amount of liquid in the extrusion mixture, expressed as LOI is in the range of 20-80%

The resulting shaped catalyst composition can, after an optional drying step, be optionally calcined. Calcination however is not essential to the process of the invention. If a calcination is carried out in the process of the invention, it can be done at a temperature of, e.g., from 100°-600°C and preferably 350° to 500°C for a time varying from 0.5 to 48 hours. The drying of the shaped particles is generally carried out at temperatures above 100°C.

Additional process steps:

In a preferred embodiment of the invention, the catalyst composition is subjected to spray drying, (flash) drying, milling, kneading, or combinations thereof prior to shaping. These additional process steps can be conducted either before or after a binder is added, after solid-liquid separation, before or after calcination and subsequent to re-wetting. It is believed that by applying any of the above-described techniques of spray drying, (flash) drying, milling, kneading, or combinations thereof, the degree of mixing between the bulk catalyst composition and the binder material is improved. This applies to both cases where the binder material is added before or after the application of any of the above-described methods. However, it is generally preferred to add the binder material prior to spray drying and/or any alternative technique. If the binder is added subsequent to spray drying and/or any alternative technique, the resulting composition is preferably thoroughly mixed by any conventional

technique prior to shaping. An advantage of, e.g., spray drying is that no wastewater streams are obtained when this technique is applied.

It must be noted that combinations of the above-described processes with respect to the binder addition can be applied. For instance, part of the binder material can be added during the preparation of the bulk catalyst composition and part of the binder material can be added at any subsequent stage prior to shaping. Further, it is also possible to apply more than one of the abovedescribed techniques.

In all the above process steps the amount of liquid must be controlled. If, e.g., prior to subjecting the catalyst composition to spray drying, the amount of liquid is too low, additional liquid must be added. If, on the other hand, e.g., prior to extrusion of the catalyst composition, the amount of liquid is too high, the amount of liquid must be reduced by, e.g., solid liquid separation via, e.g., filtration, decantation, or evaporation and, if necessary, the resulting material can be dried and subsequently be re-wetted to a certain amount. For all the above process steps, it is within the scope of the skilled person to control the amount of liquid appropriately. Generally, it may be preferred to choose the amount of liquid during the process steps (i) and (ii) in such a way that no additional drying step is necessary prior to applying spray drying and/or any alternative technique or shaping. Further, it is preferred to carry out any of the above techniques in such a way that the resulting, e.g., spray dried and/or kneaded composition contains an amount of liquid which allows the composition to be directly shaped. Spray drying is preferably carried out at an outlet temperature in the range of 100°- 200°C and more preferably 120° - 180°C.

Apart from the binder materials described above, it is also possible to add conventional hydrodenitrogenation catalysts. These catalysts can be added in the spent, regenerated, or fresh state. In principle, it is hydroprocessing catalysts

such as conventional hydrodesulfurization and possible to add these catalysts instead of a binder material or precursor thereof. In other words, it is possible to carry out all the above-described process alternatives wherein the binder material or precursor thereof is replaced fully or in part by a conventional hydroprocessing catalyst. In principle, the conventional hydroprocessing catalyst can be added at any stage of the process of the present invention prior to the shaping step. Within the context of this description, "at any stage of the process prior to the shaping step" means: it can be added during the preparation of the bulk catalyst composition, and/or subsequent to the preparation of the bulk catalyst composition but prior to the addition of the binder material, and/or during, and/or subsequent to the addition of the binder material, but prior to spray drying or any alternative method, and/or during and/or subsequent to spray drying or any alternative method but prior to the shaping step it is possible to add a conventional hydroprocessing catalyst during the compositing step (ii) with the binder. If desired, the conventional hydroprocessing catalyst may be milled before being applied in the process of the invention.

Furthermore, a cracking component may be added during the process of the present invention. A cracking component in the sense of the present invention is any conventional cracking component such as cationic clays, anionic clays, zeolites such as ZSM-5, (ultra-stable) zeolite Y, zeolite X, ALPO's, SAPO's, amorphous cracking components such as silica-alumina, or mixtures thereof. It will be clear that some materials may act as a binder and a cracking component at the same time. For instance, silica-alumina may have at the same time a cracking and a binding function.

If desired, the cracking component may be composited with a Group VIB metal and/or a Group VIII non-noble metal prior to being composited with the bulk catalyst composition and/or prior to being added during the preparation

thereof. Compositing the cracking component with any of these metals may be carried out by impregnation of the cracking component with these materials.

The cracking component can be added at any stage of the process of the present invention prior to the shaping step. However, it is preferred to add the cracking component during the compositing step (ii) with the binder.

Generally, it depends on the envisaged catalytic application of the final catalyst composition which of the above-described cracking components is added. A zeolite is preferably added if the resulting composition shall be applied in hydrocracking or fluid catalytic cracking. Other cracking components such as silica-alumina or cationic clays are preferably added if the final catalyst composition shall be used in hydrotreating applications. The amount of cracking material that is added depends on the desired activity of the final composition and the application envisaged and thus may vary from 0 - 80 wt.%, based on the total weight of the catalyst composition

If desired, further materials can be added in addition to the metal components already added in step (i). These materials include any material that is added during conventional hydroprocessing catalyst preparation. Suitable examples are phosphorus compounds, borium compounds, fluor-containing compounds, additional transition metals, rare earth metals, fillers, or mixtures thereof.

Suitable phosphorus compounds include ammonium phosphate, phosphoric acid, or organic phosphorus compounds. Phosphorus compounds can be added at any stage of the process of the present invention prior to the shaping step and/or subsequent to the shaping step. If the binder material is peptized, phosphorus compounds can also be used for peptization. For instance, the binder

can be peptized by contacting the binder with phosphoric acid or with a mixture of phosphoric and nitric acid.

Suitable additional transition metals are, e.g., rhenium, ruthenium, rhodium, iridium, chromium, vanadium, iron, cobalt, platinum, palladium, cobalt, nickel, molybdenum, or tungsten. Nickel, molybdenum, and tungsten can be applied in the form of any of the water-insoluble nickel, molybdenum and/or tungsten components that are described above for the solid route. These metals can be added at any stage of the process of the present invention prior to the shaping step. Apart from adding these metals during the process of the invention, it is also possible to composite the final catalyst composition therewith. It is, e.g., possible to impregnate the final catalyst composition with an impregnation solution comprising any of these metals.

The processes of the present invention for preparing the bulk catalyst compositions may further comprise a sulfidation step. Sulfidation is generally carried out by contacting the catalyst composition or precursors thereof with a sulfur containing compound such as elementary sulfur, hydrogen sulfide or polysulfides. The sulfidation can generally be carried out subsequently to the preparation of the bulk catalyst composition but prior to the addition of a binder material, and/or subsequently to the addition of the binder material but prior to subjecting the catalyst composition to spray drying and/or any alternative method, and/or subsequently to subjecting the composition to spray drying and/or any alternative method but prior to shaping, and/or subsequently to shaping the catalyst composition. It is preferred that the sulfidation is not carried out prior to any process step that reverts the obtained metal sulfides into their oxides. Such process steps are, e.g., calcination or spray drying or any other high temperature treatment in the presence of oxygen. Consequently, if the catalyst composition is

subjected to spray drying and/or any alternative technique, the sulfidation should be carried out subsequent to the application of any of these methods.

Additionally to, or instead of, a sulfidation step, the bulk catalyst composition may be prepared from at least one metal sulfide. If, e.g. the solid route is applied in step (i), the bulk catalyst component can be prepared from nickel sulfide and/or molybdenum sulfide and/or tungsten sulfide.

If the catalyst composition is used in a fixed bed processes, the sulfidation is preferably carried out subsequent to the shaping step and, if applied, subsequent to the last calcination step. Preferably, the sulfidation is carried out *ex situ*, i.e., the sulfidation is carried out in a separate reactor prior to loading the sulfided catalyst composition into the hydroprocessing unit. Furthermore, it is preferred that the catalyst composition is both sulfided *ex situ* and *in situ*.

Catalyst Compositions of this Invention

The present invention further refers to catalyst compositions obtainable by any of the above-described processes. Furthermore, the present invention pertains to a catalyst composition comprising bulk catalyst particles wherein the bulk catalyst particles comprise 30 - 100 wt.% of at least one Group VIII non-noble metal and at least one Group VIB metal, based on the total weight of the bulk catalyst particles, calculated as metal oxides and wherein the bulk catalyst particles have a surface area of at least 10 m²/g.

Catalyst compositions comprising bulk catalyst particles comprising one Group VIII non-noble metal and two Group VIB metals are preferred. It has been found that in this case, the bulk catalyst particles are sintering-resistant. Thus the active surface area of the bulk catalyst particles is maintained during

use. The molar ratio of Group VIB to Group VIII non-noble metals ranges generally from 10:1 - 1:10 and preferably from 3:1 - 1:3. In the case of a core-shell structured particle, these ratios of course apply to the metals contained in the shell. If more than one Group VIB metal is contained in the bulk catalyst particles, the ratio of the different Group VIB metals is generally not critical. The same holds when more than one Group VIII non-noble metal is applied. In the case where molybdenum and tungsten are present as Group VIB metals, the molybdenum:tungsten ratio preferably lies in the range of 9:1 - 1:9. Preferably the Group VIII non-noble metal comprises nickel and/or cobalt. It is further preferred that the Group VIB metal comprises a combination of molybdenum and tungsten. Preferably, combinations of nickel/molybdenum/tungsten and cobalt/molybdenum/tungsten and nickel/cobalt/molybdenum/tungsten are used. These types of precipitates appear to be sinter-resistant. Thus, the active surface area of the precipitate is remained during use.

The metals are preferably present as oxidic compounds of the corresponding metals, or if the catalyst composition has been sulfided, sulfidic compounds of the corresponding metals.

In the following the bulk catalyst particles (in the following designated as "particles") which are present in the catalyst composition of the present invention will be described in more detail:

Preferably the particles have a surface area of at least 50 m²/g and more preferably of at least 100 m²/g measured VIB the B.E.T. method. It is furthermore preferred that the particles comprise 50 - 100 wt.%, and even more preferably 70 - 100 wt.% of at least one Group VIII non-noble metal and at least one Group VIB metal, based on the total weight of the particles, calculated as

metal oxides. The amount of Group VIB and Group VIII non-noble metals can easily be determined VIB TEM-EDX.

It is desired that the pore size distribution of the particles is approximately the same as the one of conventional hydrotreating catalysts. More in particular, these particles have preferably a pore volume of 0.05 - 5 ml/g, more preferably of 0.1 - 4 ml/g, still more preferably of 0.1 - 3 ml/g and most preferably 0.1 - 2 ml/g determined by nitrogen adsorption. Preferably, pores smaller than 1 nm are not present. Furthermore these particles preferably have a median diameter of at least 50 nm, more preferably at least 100 nm, and preferably not more than 5000 μm and more preferably not more than 3000 μm . Even more preferably, the median particle diameter lies in the range of 0.1 - 50 μm and most preferably in the range of 0.5 - 50 μm .

It was found that the bulk catalyst particles have a characteristic X-ray diffraction pattern which differs from catalysts obtained by co-mixing and conventional hydroprocessing catalysts obtained by impregnation. The X-ray diffraction pattern of the bulk catalyst particles comprises, and preferably essentially consists of, peaks characteristic to the reacted metal components. If, e.g., nickel hydroxy-carbonate has been contacted with a molybdenum and tungsten component as described above, the resulting bulk catalyst particles are characterized by an X-ray diffraction pattern which comprises peaks at d values of (4.09), 2.83, 2.54, 2.32, 2.23, 1.71, (1.54), 1.47. Values in brackets indicate that the corresponding peaks are rather broad and/or have a low intensity or are not distinguished at all. The term "the X-ray diffraction pattern essentially consists of " these peaks means that apart from these peaks, there are essentially no further peaks contained in the diffraction pattern. The precipitate for catalyst obtained by the solution route has a characteristic X-ray diffraction pattern which

differs from catalyst obtained by co-mixing and conventional hydroprocessing catalysts obtained by impregnation. For instance the X-ray diffraction pattern of a Ni-Mo-W precipitate as prepared by the solution route has peaks at d values of 2.52, 1.72 and 1.46.

Generally, it is possible to perform the above-described process in such a way to obtain bulk catalyst particles characterized by an X-ray diffraction pattern that does contain virtually no peak characteristic to the metal components applied in this process as starting materials. Of course, if desired, it is also possible to choose the amounts of metal components in such a way as to obtain bulk catalyst particles characterized by an X-ray diffraction pattern still comprising one or more peaks characteristic to at least one of these metal components. If, e.g., a high amount of the metal component which is at least partly in the solid state during contacting is added, or if this metal component is added in the form of large particles, small amounts of this metal component may be traced in the X-ray diffraction pattern of the resulting bulk catalyst particles.

Generally, if the solid route is applied, at least one of the metals is anisotropically distributed in the particles. The metal of the metal component that is at least partly in the solid state during the solid route is generally concentrated in the inner part, i.e., the core of the final particles. Generally, the concentration of this metal in the outer part, i.e., the shell of the particle is at most 95% and in most cases at most 90% of the concentration of this metal in the core of the particles. Further, it has been found that the metal of a metal component that is applied in the solute state during the solid route is also anisotropically distributed in the particles. More in particular, the concentration of this metal in the core of the particles is generally lower than the concentration of this metal in the shell. Still more in particular, the concentration of this metal in the core of the particles is at most 80% and frequently at most 65% and often

at most 50% of the concentration of this metal in the shell. It must be noted that the above-described anisotropic metal distributions can be found in the composition of the invention, independently upon whether the composition has been calcined or not and/or sulfided.

In the above cases, the shell has generally a thickness of 50 - 1000 nm and preferably of 100 - 500 nm. The amount of these particles in the catalyst composition of the invention preferably lies in the range of 5 - 100 wt.%, based on the total weight of the catalyst composition.

As previously been mentioned, the catalyst composition comprises additionally a suitable binder material. Suitable binder materials are preferably those described above. The particles are embedded in the binder material that functions as glue to hold the particles together. Preferably, the particles are homogeneously distributed within the binder. The presence of the binder thus leads generally to an increased mechanical strength of the final catalyst composition. Generally, the catalyst composition of the invention has a mechanical strength, expressed as side crush strength of at least 1 lb./mm and preferably of at least 3 lb./mm (measured at extrudates with a diameter of 1 - 2 mm). The binder material generally contains 0 - 90 wt.% of the Group VIB and Group VIII non-noble metals which are also contained in the particles. The binder material generally even contains these metals if it has not been composited with any of these metals prior to being combined with the bulk catalyst composition of step (i).

The amount of binder depends on the desired activity of the catalyst composition. Binder amounts from 0 - 95 wt.% of the total composition can be suitable, depending on the envisaged catalytic application. However, to take advantage of the unusual high activity of the composition of the present

invention, binder amounts are generally in the range of 0.5 - 75 wt.% of the total composition.

If desired, the catalyst composition may comprise a suitable cracking component. Suitable cracking components are preferably those described above. The amount of the cracking component is preferably in the range of 0 - 80 wt.%, based on the total weight of the catalyst composition.

Also as previously stated, the catalyst composition may comprise conventional hydroprocessing catalysts. The binder materials and cracking components of the conventional hydroprocessing catalyst generally comprise any of the above-described binder materials and cracking components. The hydrogenation metals of the conventional hydroprocessing catalyst generally comprise Group VIB and Group VIII non-noble metals such as combinations of nickel or cobalt with molybdenum or tungsten. Suitable conventional hydroprocessing catalysts are, e.g., hydrotreating catalysts. These catalysts can be in the spent, regenerated, or fresh state.

Furthermore, the catalyst composition may comprise any compound that is conventionally present in hydroprocessing catalysts such as phosphorus compounds, additional transition metals, rare earth metals, or mixtures thereof. Suitable additional transition metals are, e.g., rhenium, ruthenium, rhodium, iridium, chromium, vanadium, iron, cobalt, platinum, palladium, cobalt, nickel, molybdenum, or tungsten. All these metal compounds generally are present in the oxidic form if the catalyst composition has been calcined and/or in the sulfided form if the catalyst composition has been sulfided.

The surface area of the catalyst composition preferably is at least 40 m²/g, more preferably at least 80 m²/g and most preferably at least 120 m²/g. The total

pore volume of the catalyst composition is preferably at least 0.05 ml/g and more preferably at least 0.1 ml/g as determined by water porosimetry. To obtain catalyst compositions with high mechanical strength, it may be desirable that the catalyst composition of the invention has a low macroporosity.

Characterization Methods

1. Side crush strength determination

First, the length of, e.g., an extrudate particle is measured, and then the extrudate particle is subjected to compressive loading by a movable piston. The force required to crush the particle is measured. The procedure is repeated with at least 40 extrudate particles and the average is calculated as force (lbs.) per unit length (mm).

2. Water porosimetry

The pore volume of a sample is determined by filling the pore space to saturation with water. The quantity of water is determined by its volume added or the weight increase of the sample. The pores space can be filled by incrementally adding water from a burette to the sample, with vigorous shaking after each addition, until the first sign of wetness at the outside of the sample appears. Another possibility is to saturate the sample contained in a tube fitted with a porous bottom with water in an ultrasound bath. The excess water (the water not residing in the pores) is removed by centrifugation and the difference in the dry and saturated catalyst weights is then used to determine the total water uptake. From this, the pore volume is calculated.

3. Determination of the lose on ignition (LOI)

A sample is mixed well to prevent inhomogeneity. The weighed and mixed sample is transferred to a preheated and weighed crucible. The crucible is

then put in a drying oven or cold muffle furnace and the temperature is increased. The sample is dried or ignited at this temperature for one hour. The crucible containing the dried or ignited sample is cooled in a desiccator and weighed again.

The LOI is determined according to the following formula

$$\%LOI = \frac{(b-c)}{a} \times 100$$

where a is weight of the sample (in gram), b is the mass of the crucible and the sample before drying and/or ignition (in gram), and c is the weight of the crucible and the sample after drying and/or ignition (in gram).

In the process according to the present invention, a Group VIII non-noble metal-containing compound in solution and a Group VIB metal-containing compound in solution are reacted. Thus, the metal compounds are in the solute state when reacted to obtain a precipitate. The Group VIII non-noble metal-containing compound and the Group VIB metal-containing compound may be in solution when added to the reaction mixture or else will become dissolved when present in the reaction mixture. In the latter case, the metals are actively dissolved in the reaction mixture, for instance by stirring, increasing the amount of solvent, changing the temperature, changing the pressure, or changing the pH. The metals may be dissolved in any protic liquid such as water, carboxylic acids, lower alcohols such as ethanol, propanol, etc., or mixtures thereof. Of course, a protic liquid must be chosen which does not interfere with the precipitation reaction.

If soluble salts are added as such, they will dissolve in the reaction mixture. They will subsequently be precipitated with the Group VIB metal. Within the context of this description soluble means soluble in the solvent at the temperature and pH of the reaction mixture. Suitable nickel, iron and cobalt salts which are soluble in water are nitrates, hydrated nitrates, chlorides, hydrated chlorides, sulfates, hydrated sulfates, heteropolyanion compounds of Ni-Mo-W (soluble in boiling water), heteropolyanion compounds of Co-Mo-W (soluble in boiling water). It is also possible to add Group VIII non-noble metal-containing compounds which are not in solution at the time of addition, but where solution is effected in the reaction mixture. Examples of these compounds are metal compounds which contain so much crystal water that upon temperature increase the metal compound will dissolve in its own crystal water. Further, non-soluble metal salts may be added in suspension or as such and solution is effected in the reaction mixture. Suitable non-soluble metal salts are heteropolyanion compounds of Co-Mo-W (moderately soluble in cold water), heteropolyanion compounds of Ni-Mo-W (moderately soluble in cold water).

Suitable Group VIB metals are chromium, molybdenum, tungsten, or mixtures thereof. Suitable chromium, molybdenum, and tungsten compounds are soluble chromium, molybdenum, and tungsten salts. Said salts can be added to the reaction mixture in solution, wetted, or as such. If soluble salts are added as such, they will dissolve in the reaction mixture. They will subsequently be precipitated with the Group VIII non-noble metal. Suitable Group VIB metal salts which are soluble in water are ammonium salts such as ammonium dimolybdate, ammonium tri-, tetra-, hepta-, octa-, and tetradeca- molybdate, ammonium para-, meta-, hexa-, and polytungstate, alkali metal salts, silicic acid salts of Group VIB metals such as molybdic silicic acid, molybdic silicic tungstic acid, tungstic acid, metatungstic acid, pertungstic acid, heteropolyanion compounds of Mo-P, Mo-Si, W-P, and W-Si. It is also possible to add Group

VIB metal-containing compounds which are not in solution at the time of addition, but where solution is effected in the reaction mixture. Examples of these compounds are metal compounds which contain so much crystal water that upon temperature increase they will dissolve in their own metal water. Further, non-soluble metal salts may be added in suspension or as such, and solution is effected in the reaction mixture. Suitable non-soluble metal salts are heteropolyanion compounds of Co-Mo-W (moderately soluble in cold water), heteropolyanion compounds of Ni-Mo-W (moderately soluble in cold water).

As will be clear from the above, it is possible to add the Group VIII non-noble metal containing compound and the Group VIB metal-containing compound in various ways, at various temperatures and pHs, in solution, in suspension, and as such, simultaneously and sequentially. Five precipitation methods will be described in more detail:

1. Simultaneous precipitation at a constant pH, in which process a Group VIII non-noble metal-containing acid salt compound is added slowly to a reaction vessel containing a protic liquid which is kept at a constant temperature, with the pH being kept constant by adding a base containing Group VIB metal-containing compound solution. The pH is set such that (at the chosen reaction temperature) precipitation occurs. The Group VIII metal-containing compound is added in solution or as such. It was found that the precipitate prepared by this method had a relatively large particle size depending on the dosing speed (with low dosing speed larger than 10 μm (as measured in the slurry with near forward scattering (Malvern)) and a large surface area of 100 m^2/g or more.
2. Simultaneous precipitation, in which process both the Group VIII non-noble metal-containing compound and the Group VIB metal-containing

compound are added slowly and simultaneously to a reaction vessel containing protic liquid and a compound which decomposes upon temperature increase and thereby increases or decreases the pH. The temperature of the reaction vessel is kept at the decomposition temperature of said compound. In this case precipitation is effected by pH change, and the pH at the beginning of the reaction differs from the final pH after precipitation. It was found that the precipitation obtained with this method had a relatively large particle size (larger than 15 μm).

3. Precipitation, in which process the Group VIII non-noble metal-containing compound is added slowly to a reaction vessel containing Group VIB metal-containing compound dissolved in protic liquid (*or vice versa*) and a compound which decomposes upon temperature increase and thereby increases or decreases the pH. The temperature of the reaction vessel is kept at the decomposition temperature of said compound. In this case precipitation is effected by pH change, and the pH at the beginning of the reaction differs from the final pH after precipitation. It was found that the precipitate obtained with this method had a relatively small particle size (between 1 and 10 μm). It was further found that the amount of Group VIB metal compound which actually ended up in the precipitate was larger than in any of the other precipitation methods described above.
4. Precipitation at a constant pH, in which process the Group VIII non-noble metal-containing compounds is added slowly to a reaction vessel containing Group VIB metal-containing compound dissolved in protic liquid or vice versa. The pH is kept such that (at the chosen reaction temperature) precipitation occurs by adding acid or base to the reaction vessel.

5. Solution of the metal compounds in their own crystal water with subsequent evaporation of the water so that precipitation occurs. In this method the Group VIII non-noble metal-containing compound and the Group VIB metal-containing compound are mixed in a reaction vessel and heated. After solution of the metals the water is evaporated, optionally under vacuum, to effect precipitation.

One embodiment of the present invention pertains to a process for the preparation of a catalyst composition comprising a Group VIII non-noble metal and a Group VIB metal wherein a Group VIII non-noble metal-containing compound in solution and a Group VIB metal-containing compound in solution are reacted in a reaction mixture to obtain a precipitate, with the proviso that the precipitate is not nickel molybdate in which at least a portion but less than all of the molybdenum is replaced by tungsten.

Subsequently to precipitation, the precipitate may be isolated from the liquid and dried. All conventional isolation methods such as filtration, centrifugation, decantation may be used. Also all conventional drying methods are suitable such as oven drying, spray-drying, etc. The precipitate can also be dried at room temperature.

Optionally, the precipitate is thermally treated in oxygen-containing atmosphere such as air, steam, in steam and oxygen-containing atmosphere or in inert atmosphere. Said thermal treatment is conducted at a temperature between 100-600°C, preferably between 350°-500°C.

In a further embodiment of the solution method of the present invention a filler is added to the reaction mixture and/or precipitate. Fillers may be added to

the catalyst composition to dilute the catalyst when it is too active or to adjust the density. These fillers can be added either in suspension or as such at any stage of the process and combined with any other component added. Suitable fillers include used hydroprocessing catalyst, regenerated hydroprocessing catalysts, fresh hydroprocessing catalyst, clay, and mixtures thereof.

The precursor compound can also be readily prepared by one of several methods, including a variation of the boiling decomposition method used by Teichner and Astier in which a tungsten compound is added to the initial mixture of a molybdenum salt, a nickel salt and ammonium hydroxide. Direct precipitation and pH controlled precipitation may also be used to prepare the precursor compound. In all cases, however, water soluble salts of nickel, molybdenum and tungsten are employed.

Preferably, the molybdenum and tungsten salts are ammonium compounds, e.g., ammonium molybdate, ammonium metatungstate, while the nickel salt may be the nitrate or hydrated nitrates.

In the boiling decomposition method, the salts are dissolved in water to make an acidic solution, after which additional NH_4OH is added to make a basic solution. The solution is then heated to boiling to drive off ammonia and form a precipitate which is filtered and dried, e.g., at 100-125°C.

In the direct precipitation method, initially the molybdate and tungstate salts are dissolved in water, NH_4OH is added to form a basic solution, and the solution is warmed. A warm, e.g., 90°C, nickel salt solution (aqueous) is slowly added to the initial solution, a precipitate is formed, the solution is hot filtered and dried. In either the boiling decomposition method or the direct precipitation method, washing of the filtrate is minimized to prevent leaching.

In general, all of the components, the Ni, Mo, W, NH_3 , are mixed in solution together and heated to a $\text{pH} < 7$ to form the precipitate, i.e., the precursor compound. This may be accomplished by either of two methods: (1): adding all of the components together with an excess of ammonia to dissolve the components and then heating to drive off the ammonia such that the $\text{pH} < 7$ (heating may be at less than 100°C , preferably about $50\text{-}90^\circ\text{C}$); or (2) adding together one or more separate solutions of each component such that the final pH is < 7 ; in each case recovering the resulting precipitate.

In another embodiment, a binder can be added to the bulk mixed metal oxide to maintain particle integrity. The binder can be silica, alumina, silica-alumina or other materials generally known as particle binders. When utilizing a binder, the amount may range from about 1-30 wt% of the finished catalyst, preferably about 5-26 wt% of the finished catalyst.

After recovering the precursor product, regardless of preparation method, the precursor is decomposed at temperatures ranging from about $300\text{-}450^\circ\text{C}$ in a suitably inert or air atmosphere.

The decomposed precursor can be sulfided or pre-sulfided by a variety of known methods. For example, the decomposition product can be contacted with a gas comprising H_2S and hydrogen, e.g., 10% $\text{H}_2\text{S}/\text{H}_2$, at elevated temperatures for a period of time sufficient to sulfide the decomposition product, usually at the point of H_2S breakthrough in the exit gas. Sulfiding can also be effected, in situ, by passing a typical feedstock containing sulfur over the decomposition product.

Any hydrocarbon containing feed which also contains nitrogen may be treated with the enhanced catalysts of this invention. Thus, the HDN process

While the invention described herein shows enhanced activity for hydrodenitrogenation, most HDN catalysts will also show hydrodesulfurization (HDS) activity. Consequently, the catalysts and processes described herein will be useful on feeds containing both nitrogen and sulfur, and will be particularly useful on feeds high in nitrogen.

The following examples will serve to illustrate, but not limit, this invention.

Example 1. Preparation of $\text{NH}_4\text{-Ni-Mo-O}$ Phase (boiling decomposition as per Teichner and Astier procedure):

In a 1 liter flask, 26.5 g ammonium molybdate (0.15 moles Mo) and 43.6 g nickel nitrate hexahydrate (0.15 moles Ni) were dissolved in 300 cc of water so that the resulting pH equaled 4.3. To this solution, a concentrated NH_4OH solution was added. At first, a precipitate formed which on further addition of NH_4OH dissolved to give a clear blue solution with a pH of 8.3, and additional NH_4OH (~250cc) was added until a pH of 10 was reached. The solution was heated to 90°C for 3 h during which ammonia gas evolved and a green precipitate formed. The final pH lay between 6.8 and 7. The suspension was cooled to room temperature, filtered, washed with water and dried at 120°C overnight. About 18.6g of material was obtained. The sample analyzed for Ni at 26.6 wt.% and Mo at 34 wt.%. The X-ray diffraction spectra of the phase matches the pattern reported by Teichner.

Example 2. Preparation of $\text{NH}_4\text{-Ni-Mo}_.5\text{W}_.5\text{-O}$ by boiling decomposition:

In a 1 liter flask, 13.2 g ammonium molybdate (0.075 moles Mo), 18.7 g ammonium metatungstate (.075 moles W) and 43.6 g nickel nitrate hexahydrate (0.15 moles Ni) were dissolved in 300cc of water so that the resulting pH equaled 4.3. To this solution, a concentrated NH_4OH solution (~600cc) was added until the pH reached 10. At this point, some precipitate remained. The solution was refluxed at $\sim 100^\circ\text{C}$ for 3 h. During this heating, the precipitate dissolved to give a clear blue solution and on further heating, a green precipitate formed. The heating was continued until the pH reached between 6.8 and 7. The

Two solutions were prepared with the same amounts of nickel, tungsten, molybdenum and ammonium hydroxide are described in Example 3 (solutions A and B) except that each solution contained about 700 cc of water. The two solutions were added into a separate vessel initially containing 400 cc of water held at 90°C. Solution B (the acidic solution) was pumped into the vessel at a constant rate of ~15cc/min, while solution A is added through a separate pump which is under feedback PC control and set to maintain the pH at 6.5. On mixing

the two solutions a precipitate forms. The slurry was stirred at 90°C for 30 minutes, filtered hot, washed with hot water, and dried at 120°C.

Example 5. Catalytic Evaluation Using Dibenzothiophene (DBT):

1.5-2 g of the catalysts of Examples 1-4 were placed in a quartz boat which was in turn inserted into a horizontal quartz tube and placed into a Lindberg furnace. The temperature was raised to 370°C in about one hour with N₂ flowing at 50 cc/m, and the flow continued for 1.5 h at 370°C. N₂ was switched off and 10% H₂S/H₂ then added to the reactor at 20 cc/m, the temperature increased to 400°C, and held there for 2 hours. The heat was then shut off and the catalyst cooled in flowing H₂S/H₂ to 70°C, at which point this flow was discontinued and N₂ was added. At room temperature, the quartz tube was removed and the material transferred into a N₂ purged glove box. Catalysts were evaluated in a 300cc modified Carberry batch reactor designed for constant hydrogen flow. The catalyst was piled and sized to 20/40 mesh and one gram was loaded into a stainless steel basket, sandwiched between a layer of mullite beads. 100 cc of liquid feed, containing 5 wt% dibenzothiophene in decalin was added to the autoclave. A hydrogen flow of 100 cc/min was passed through the reactor and the pressure was maintained at 3150kPa using a back pressure regulator. The temperature was raised to 350°C at 5-6 deg/min and run until either 50% DBT was converted or until 7 hours was reached. A small aliquot of product was removed every 30 minutes and analyzed by GC. Rate constants for the overall conversion as well as the conversion to the reaction products biphenyl (BP) and cyclohexylbenzene (CHB) were calculated as described by M. Daage and R. R. Chianelli [J. Cat. 149, 414-27 (1994)] and are shown in Table 1. As described in that article, high selectivities to cyclohexylbenzene relative to BP during the desulfurization reaction are a good indication of a catalyst with high

A series of catalysts were prepared in accordance with the general preparation scheme of example 2 (i.e., boiling decomposition) but varying the Mo and W relative ratios by changing the amount of ammonium molybdate and ammonium metatungstate added to the solutions. Decomposition was effected as

described in Example 5. The catalysts so prepared are shown in Table 2 along with their catalytic activities for DBT measured as described in Example 5.

Table 2. Comparison of Activity in DBT Conversion Tests with Variation in Relative W and Mo content

Catalyst	Sample	Ammonium Molybdate (g)	Ammonium Metatungstate (g)	Nickel Nitrate Hexahydrate (g)	K _{total} @ 350°C	CHB/BP @ 350°C
NH ₄ -NiW-O	18983-97	0	36.95	43.62	128	11.3
NH ₄ -NiMo ₁ W ₉ -O	18983-125	2.65	33.62	43.62	132	14.1
NH ₄ -NiMo ₃ W ₇ -O	18983-101	7.94	25.87	43.62	154	11.6
NH ₄ -NiMo ₅ W ₅ -O	18357-109	13.17	18.74	43.62	171	10.2
NH ₄ -NiMo ₇ W ₃ -O	18983-95	18.54	11.09	43.62	158	11.5
NH ₄ -NiMo ₉ W ₁ -O	18983-92	23.83	3.69	43.62	141	10.5

The data show that the most active catalyst contains an approximately equimolar mixture of tungsten and molybdenum.

Example 7.

A series of catalysts were prepared as described in Example 3 (direct precipitation) in which equimolar mixtures of Mo and W were precipitated but the nickel content was varied. Decomposition was effected as described in Example 5. The catalysts so prepared are shown in Table 3 along with their catalytic activities for DBT measured as described in example 5.

Table 3. Variation of Nickel Content in $\text{NH}_4\text{-Ni-Mo}_{.5}\text{W}_{.5}\text{-O}$ Catalysts

Catalyst	Sample	Ammonium molybdate (g)	Ammonium metatungstate (g)	Nickel nitrate hexahydrate (g)	K_{total} @ 350°C	CHB/ BP @ 350°C
$\text{NH}_4\text{-Ni}_{0.75}\text{Mo}_{.5}\text{W}_{.5}\text{-O}$	19086-110	17.65	24.6	43.65	171	13.0
$\text{NH}_4\text{-Ni}_{1.0}\text{Mo}_{.5}\text{W}_{.5}\text{-O}$	19086-82	17.65	24.6	58.2	167	12.4
$\text{NH}_4\text{-Ni}_{1.25}\text{Mo}_{.5}\text{W}_{.5}\text{-O}$	19086-111	17.65	24.6	72.75	174	11.0
$\text{NH}_4\text{-Ni}_{1.5}\text{Mo}_{.5}\text{W}_{.5}\text{-O}$	19086-112	17.65	24.6	87.3	148	9.55

Catalytic performance does not change substantially with variations in Ni from 0.75 to 1.5, although K appears to go through a maximum at about 1.25 Ni.

Example 8. A series of catalysts were prepared in which the quantity of NH_4OH used in the preparation was varied. The catalysts were prepared in accordance to the procedure described in Example 3 except that the amount of

NH₄OH in solution A was varied to change to NH₄OH/Ni molar ratio when the two solutions were mixed. Decomposition was effected as described in Example 5. The catalysts so prepared are shown in Table 4 along with their catalytic activities for DBT measured as described in Example 5.

Table 4. Variation in NH₄OH Addition to Preparation

Catalyst NH ₄ OH/Ni mole ratio	Sample	Ammonium molybdate (g)	Ammonium metatungstate (g)	Nickel nitrate hexahydrate (g)	cm ³ conc NH ₄ OH	K _{total} l @ 350°C	K _{CH} B/BP @ 350°C
1:2	19086-96	17.65	24.6	43.65	6.8	102	10.5
1:1	19086-97	17.65	24.6	58.2	14	137	10.4
2:1	19086-82	17.65	24.6	72.75	30	167	12.4
3:1	19086-104	17.65	24.6	87.3	41	164	11.4
4:1	19086-106	17.65	24.6	87.3	55	161	12.1

While decomposition of the precursor compound will drive off most, if not all, of the ammonium portion of the precursor, the preparation of the precursor and the catalytic utility of the decomposition product can be affected by the amount of NH₄OH employed. Thus, the effectiveness of the decomposition product as a catalyst is enhanced when the NH₄OH/Ni ratio in the

preparation of the precursor compound is from about 1:1 to about 4:1, preferably about 1.5:1 to about 4:1, and more preferably about 2:1 to about 4:1. While not wishing to be bound by any particular theory or mechanism, there is some evidence the $\text{NH}_4\text{OH}/\text{Ni}$ ratio causes the Ni-M-W-O phase to change in the decomposition product.

Example 9. The catalysts of examples 1 and 2 were compared against standard supported Ni-Mo catalysts for the conversion of a LSADO (low sulfur auto diesel oil feed). This feed contained 510 wppm sulfur, 50 wppm nitrogen, and 30.6% aromatics with a gravity of 39.8° API. The catalysts were tested at 579°F, 650 psig of H_2 , and 1850 SCFB/B of H_2 . The relative activities of the different catalysts are summarized in Table 5.

Table 5. Relative Hydrotreating Activities on LSADO Feed

Catalyst	Relative Volumetric HDS Activity	Relative Volumetric HDN Activity
Ni,Mo/ Al_2O_3	1	1
$\text{NH}_4\text{-NiMo-O}$	0.25	0.50
$\text{NH}_4\text{-Ni}_{1.0}\text{Mo}_{0.5}\text{W}_{0.5}\text{-O}$	1.4	2.05

The Ni, Mo/ Al_2O_3 catalyst is a standard HDN/HDS catalyst, the $\text{NH}_4\text{-Ni-Mo}$ phase is the bulk phase with no tungsten, and the $\text{NH}_4\text{-Ni}_{1.0}\text{Mo}_{0.5}\text{W}_{0.5}\text{-O}$ is the bulk phase with partial substitution of W for Mo. The $\text{NH}_4\text{-NiMo-O}$ catalyst is also representative of known compounds. The catalyst of this invention is illustrated by $\text{NH}_4\text{-Ni}_{1.0}\text{Mo}_{0.5}\text{W}_{0.5}\text{-O}$ and the data show the clear advantage of ammonium nickel tungsten molybdate for HDN activity.

Example 10. Preparation of a bulk catalyst composition according to the solid route:

657g of a Ni-Mo-W bulk catalyst composition obtained according to the procedure described in Examples 10 or 11 was added to 1362 g of an aqueous slurry containing 125g of alumina (prepared by precipitation of sodium aluminate and aluminum sulfate). The resulting Ni-Mo-W bulk catalyst - alumina composition was subsequently mixed at 80°C until an LOI of 31% was obtained. The resulting composition was subsequently extruded and the

minutes. After 30 minutes, the precipitate is filtered and washed. The precipitate is dried overnight at 120°C and calcined at 385°C.

Example 17.

The precipitation method of Example 16 was used to prepare a precipitate from ammonium dimolybdate, ammonium meta tungstate and $\text{Fe(III)(NO}_3)_3 \cdot 9 \text{H}_2\text{O}$ in 98% yield comprising 41.2 wt.% Fe_2O_3 , 21.3 wt.% MoO_3 , and 36.9 wt.% WO_3 . The surface area of the precipitate was $76 \text{ m}^2/\text{g}$. The pore volume as measured up to 60 nm by BET using the adsorption curve was 0.147 ml/g.

Example 18.

The precipitation method of Example 16 was used to prepare a precipitate from $\text{Ni(CO}_3)_2 \cdot 6\text{H}_2\text{O}$, $(\text{NH}_4)_6\text{MO}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$, and $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ in 87.7% yield comprising 52.2 wt.% NiO, 29.4 wt.% MoO_3 , and 16.6 wt.% Cr_2O_3 . The surface area of the precipitate was $199 \text{ m}^2/\text{g}$. The pore volume as measured up to 60 nm by BET using the adsorption curve was 0.276 ml/g.

Example 19.

The precipitation method of Example 16 was used to prepare a precipitate from $\text{Ni(CO}_3)_2 \cdot 6\text{H}_2\text{O}$, $(\text{NH}_4)_6 \text{H}_2\text{W}_{12}\text{O}_{40}$, and $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ in 87.7% yield comprising 44.0 wt.% NiO, 42.4 wt.% WO_3 , and 11.8 wt.% Cr_2O_3 . The surface area of the precipitate was $199 \text{ m}^2/\text{g}$. The pore volume as measured up to 60 nm by BET using the adsorption curve was 0.245 ml/g.

Example 20.

A 250N raffinate was processed at raffinate hydrocracking conditions in a small- scale pilot unit over both a conventional NiMo hydrotreating (HT) catalyst and the bulk metal catalyst. Feed quality, operating conditions and pilot plant test results are given in the table below. The relative conversion activity for the bulk

metal catalyst was 300 to 400% higher than for the conventional catalyst. The extent of saturation was also higher. Lube yields at the same product quality VI were similar for both catalysts.

	250N Raffinate Feed	Conventional NiMo HT Catalyst			Bulk Metal Catalyst		
H2 Partial Pressure , psig		1800	1800	1800	1800	1800	1800
H2 Treat Gas Rate, SCF/bbl		2408	2418	2405	2451	2449	2504
RX Temp, °C		354.3	369.9	361.6	339.9	355.4	354.5
RX LHSV, hr-1		0.7	0.7	0.7	0.7	0.7	1.4
370C+ Waxy Lube Yield, wt%	98.8	87.1	77.7	83.3	76.1	58.9	70.2
370C+ Conversion, %		11.9	21.4	15.8	23.1	40.5	29.0
Relative Conversion Catalyst Activity Versus Fresh Conventional NiMo HT Catalyst, %		66	71	69	316	304	411
Dewaxed 370C+ Product Properties							
Kinimatic Viscosity @ 40 °C, cSt	56.15	38.72	32.59	35.52	32.06	23.54	28.19
VI at -18 °C Pour	93	105	114	110	115	127	120
Saturates, wt%	65	96	95	97	99	99	99

Example 21.

An FFC light cycle gas oil (LCCO) and a Arab Medium Heavy Vacuum Gas Oil (HVGO) were processed at Stage 1 hydrocracking conditions in a small scale pilot unit over both a conventional NiMo hydrotreating (HT) catalyst and the bulk metal catalyst. Feed quality, operating conditions and pilot plant test results are given in the table below. The relative denitrogenation activity for the bulk metal catalyst was 250 to 550% higher than for the conventional catalyst.

	LCCO	HVGO	Conventional NiMo HT Catalyst		Bulk Metal Catalyst	
	Feed	Feed				
Feed			LCCO	HVGO	LCCO	HVGO
H2 Partial Pressure , psig			1200	2100	1200	2100
H2 Treat Gas Rate, SCF/bbl			4900	6300	4900	6300
RX Temp, °C			299	360	299	360
RX LHSV, hr-1			1.0	1.0	1.0	1.0
Product Nitrogen, wppm	741	858	42.3	219	28.6	22.3
Relative Denitrogenation Volume Activity, %			100.00	100.00	550.00	250 00

CLAIMS:

1. A process for preparing lubricating oil basestocks which comprises:

(a) contacting a hydrocarbon feedstock derived from at least one of thermal treatment, catalytic treatment, extraction, dewaxing or fractionation of a petroleum crude or fraction thereof, shale oil, tar sands or synthetic crude with a bulk metal catalyst under hydrocracking conditions, said catalyst comprising non-noble Group VIII metal molybdate in which at least a portion but less than all of molybdenum is replaced by tungsten; and

(b) fractionating hydrocracked feedstock to produce a distillate lubricating oil fraction.

2. A process for producing lubricating oil basestocks which comprises:

(a) feeding a hydrocarbon feedstock derived from at least one of thermal treatment, catalytic treatment, extraction, dewaxing or fractionation of a petroleum crude or fraction thereof, shale oil, tar sands or synthetic crude, to a first hydrocracking zone containing a hydrocracking catalyst wherein said hydrocracking catalyst is a bulk metal catalyst comprising non-noble Group VIII metal molybdate in which at least a portion but less than all of molybdenum is replaced by tungsten to produce a hydrotreated feedstock;

(b) hydrocracking the feedstock under hydrocracking conditions to produce a hydrocracked;

8. The process of claim 7 wherein the molar ratio of b:(c+d) is 0.75/1 to 1.5/1.
9. The process of claim 8 wherein the molar ratio of b:(c+d) is 0.75/1 to 1.25/1.
10. The process of claim 7 wherein the molar ratio of c:d is >0.1/1.
11. The process of claim 10 wherein the molar ratio of c:d is 1/10 to 10/1.
12. The process of claim 11 wherein the molar ratio of c:d is 1/3 to 3/1.
13. The process of claim 1 wherein the hydrocracking conditions include temperatures of from 300 to 480 °C, hydrogen pressures of from 1000 to 3500 psig (6995 to 24234 KPa), liquid hourly space velocities of from 0.2 to 4.0 and hydrogen treat gas rates of from 1000 to 15000 scf/B (178 to 2670 m³/m³).
14. The process of claim 2 wherein the hydrocracking conditions in the first and second hydrocracking zones include temperatures of from 300 to 480 °C, hydrogen pressures of from 1000 to 3500 psig (6995 to 24234 KPa), liquid hourly space velocities of from 0.2 to 4.0 and hydrogen treat gas rates of from 1000 to 15000 scf/B (178 to 2670 m³/m³).
15. The process of claims 1 or 2 wherein the distillate lubricating oil fraction is solvent extracted under solvent extraction conditions to produce a raffinate rich in paraffinic hydrocarbons and an extract rich in aromatic hydrocarbons.
16. The process of claim 15 wherein the raffinate is solvent or catalytically dewaxed.

17. The process of claims 1 or 2 wherein the distillate lubricating oil fraction is solvent or catalytically dewaxed.

18. The process of claim 15 wherein the solvent is furfural, phenol or N-methyl-2-pyrrolidone.

19. The process of claim 16 wherein solvent or catalytically dewaxed product is hydrofinished under hydrofinishing conditions.

20. The process of claim 17 wherein solvent or catalytically dewaxed product is hydrofinished under hydrofinishing conditions.

21. The process of claim 16 wherein catalytic dewaxing is by an eight, 10 or 12 ring molecular sieve.

22. The process of claim 17 wherein catalytic dewaxing is by an eight, 10 or 12 ring molecular sieve.

23. The process of claim 21 wherein the 10 ring molecular sieve is a zeolite or a silicoaluminophosphate.

24. The process of claim 22 wherein the 10 ring molecular sieve is a zeolite or a silicoaluminophosphate.

25. The process of claim 19 wherein the hydrofinishing conditions include a temperature of from 200 to 370 °C, pressure of from 150 to 3000 psig (1136 to 20786 kPa), liquid hourly space velocity of from 0.2 to 5.0 and a hydrogen treat rate of from 100 to 5000 scf/B (17.8 to 890 m³/m³).

26. The process of claim 20 wherein the hydrofinishing conditions include a temperature of from 200 to 370 °C, pressure of from 150 to 3000 psig (1136 to 20786 kPa), liquid hourly space velocity of from 0.2 to 5.0 and a hydrogen treat rate of from 100 to 5000 scf/B (17.8 to 890 m³/m³).

27. The process of claim 25 wherein the hydrofinishing conditions include an hydrofinishing catalyst containing at least one Group VIII metal.

28. The process of claim 26 wherein the hydrofinishing conditions include a hydrofinishing catalyst containing at least one Group VIII metal.

29. The process of claim 27 wherein the hydrofinishing catalyst is the bulk metal catalyst.

30. The process of claim 28 wherein the hydrofinishing catalyst is the bulk metal catalyst.

31. The process of claims 1 or 2 wherein the lubricating oil basestocks are Group III basestocks having at least about 90% saturates, a sulfur content less than about 0.03 wt.% and a VI of at least 120.

32. The process of claims 1 or 2 wherein the lubricating oil basestocks are Group II basestocks having at least about 90% saturates, a sulfur content less than about 0.03 wt.% and a VI less than 120.

33. The process of claim 7 wherein X is Ni or Co.

34. The process of claim 7 wherein X is Ni.

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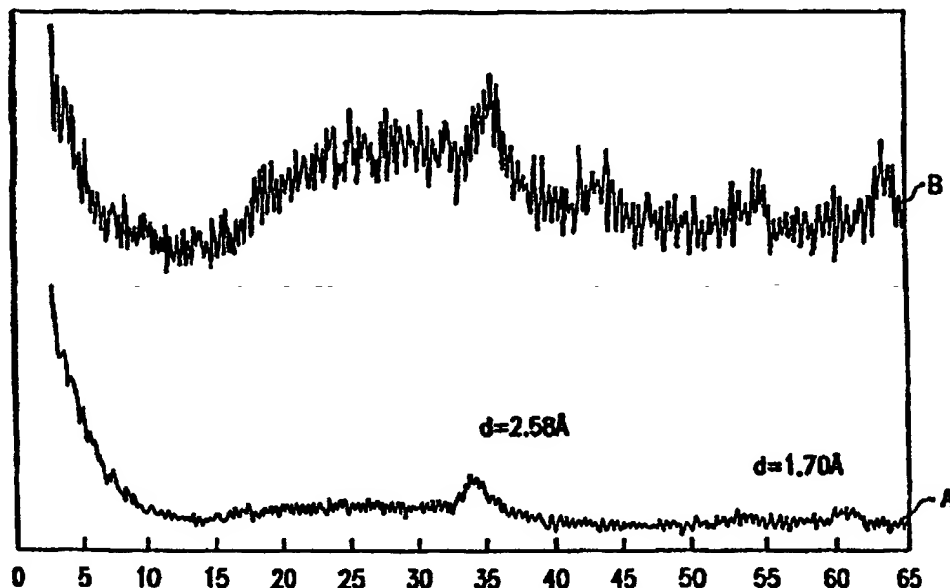
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(54) Title: HYDROCRACKING PROCESS USING BULK GROUP VIII/GROUP VIB CATALYSTS



(57) Abstract

Hydrocracking process for hydrocracking petroleum and chemical feedstocks using bulk Group VIII/Group VIB catalysts. Preferred catalysts include those comprised of Ni-Mo-W.

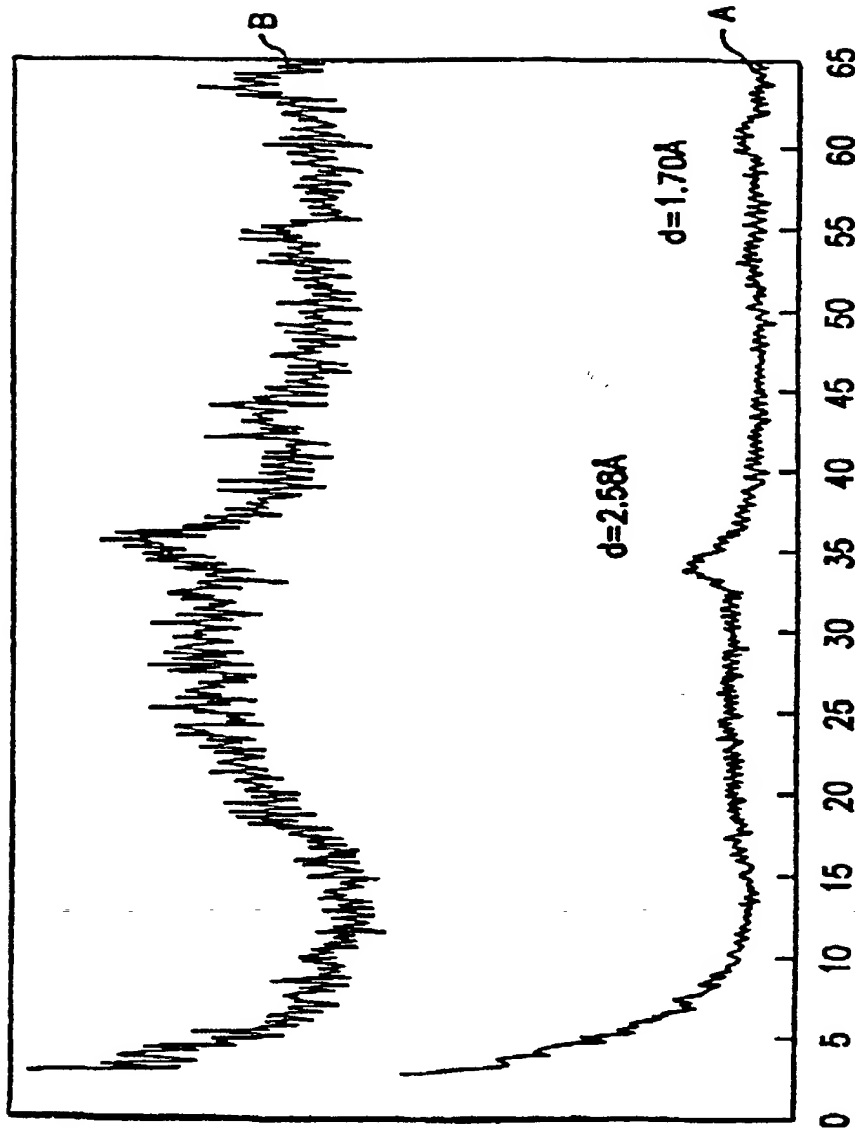


FIG. 1

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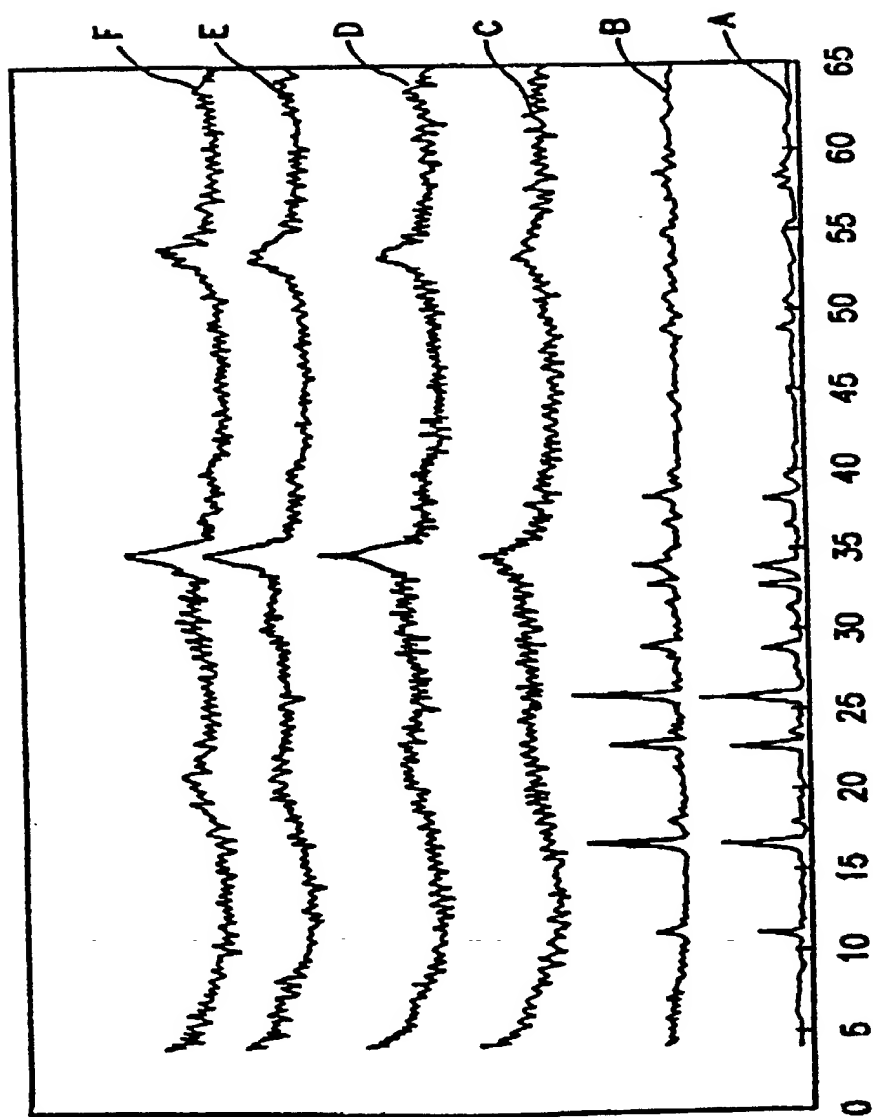


FIG. 2

DECLARATION FOR PATENT APPLICATION

09869990 111503

Docket Number
JHT-0004

As a below named Inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint Inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **HYDROCRACKING PROCESS USING BULK GROUP VIII/GROUP VIB CATALYSTS**, the specification of which is attached hereto unless the following box is checked:

☒ was filed on **January 14, 2000** as United States Application Number _____ or PCT International Application Number **PCT/US00/01004** and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56

I hereby claim foreign priority benefits under 35 U.S.C. § 119 (a)-(d) or § 365(b) of any foreign application(s) for patent or Inventor's certificate, or § 365 (a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or Inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)

☐

☐

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

_____ (Application Number)	_____ (Filing Date)
_____ (Application Number)	_____ (Filing Date)

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose the information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

09/231,156 (Application Number)	January 15, 1999 (Filing Date)	Patented (Status--patented, pending, abandoned)
08/900,389 (Application Number)	July 15, 1997 (Filing Date)	Patented (Status--patented, pending, abandoned)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Names	Registration Numbers
James H. Takemoto	28,272
Gerard J. Hughes	41,855
Paul E. Purwin	29,203

ADDRESS ALL TELEPHONE CALLS TO: James H. Takemoto at telephone number (225) 977-4584
 ADDRESS ALL CORRESPONDENCE TO: ExxonMobil Research & Engineering Company
 (formerly Exxon Research & Engineering Company)
P.O. Box 900
Annandale, New Jersey 08801-0900

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor

<u>Stuart</u> GIVEN NAME	<u>Leon</u> MIDDLE INITIAL OR NAME	<u>Soled</u> FAMILY (OR LAST NAME)
-----------------------------	---------------------------------------	---------------------------------------

Inventor's Signature

Date June 25, 2001 Country of Citizenship United States of America
 City of Residence Pittstown, New Jersey
 Post Office Address 21 Cooks Cross Road
Pittstown, New Jersey 08867

☒ Additional Inventors are being named on separately numbered sheets attached hereto.

**ADDED PAGE TO DECLARATION FOR PATENT APPLICATION
FOR SIGNATURE BY SECOND AND SUBSEQUENT INVENTORS****Full name of second joint inventor, if any**Kenneth
GIVEN NAMELloyd
MIDDLE INITIAL OR NAMERiley
FAMILY (OR LAST NAME)**Inventor's Signature**Kenneth Lloyd RileyDate June 29, 2001

Country of Citizenship

United States of AmericaCity of Residence Baton Rouge, LouisianaPost Office Address 1289 Rodney DriveBaton Rouge, Louisiana 70808**Full name of third joint inventor, if any**Gary
GIVEN NAMEP.
MIDDLE INITIAL OR NAMESchleicher
FAMILY (OR LAST NAME)**Inventor's Signature**Gary P. SchleicherDate June 29, 2001

Country of Citizenship

CanadaCity of Residence Baton Rouge, LouisianaPost Office Address 872 Pastureview DriveBaton Rouge, Louisiana 70810**Full name of fourth joint inventor, if any**Richard
GIVEN NAMEA.
MIDDLE INITIAL OR NAMEDemmin
FAMILY (OR LAST NAME)**Inventor's Signature**Richard A. DemminDate August 24, 2001

Country of Citizenship

United States of AmericaCity of Residence Highland Park, New JerseyPost Office Address 424 Dennison StreetHighland Park, New Jersey 08904**Full name of fifth joint inventor, if any**William
GIVEN NAMEL.
MIDDLE INITIAL OR NAMESchuetz
FAMILY (OR LAST NAME)**Inventor's Signature**Deceased - completed on added page

Date

Country of Citizenship

United States of AmericaCity of Residence New Roads, LouisianaPost Office Address 9254 False River RoadNew Roads, Louisiana 70760

**ADDED PAGE TO DECLARATION FOR PATENT APPLICATION
FOR SIGNATURE BY SECOND AND SUBSEQUENT INVENTORS****Full name of sixth joint inventor, if any**

6-a

<u>Ian</u>	<u>Alfred</u>	<u>Cody</u>
GIVEN NAME	MIDDLE INITIAL OR NAME	FAMILY (OR LAST NAME)

Inventor's Signature Ian A. Cody

Date July 27 2001 Country of Citizenship Canada

City of Residence Baton Rouge, Louisiana LA

Post Office Address 19516 Cape Hart Court

Baton Rouge, Louisiana 70810

Full name of seventh inventor, if any

_____	_____	_____
GIVEN NAME	MIDDLE INITIAL OR NAME	FAMILY (OR LAST NAME)

Inventor's Signature _____

Date _____ Country of Citizenship _____

City of Residence _____

Post Office Address _____

Full name of eighth joint inventor, if any

_____	_____	_____
GIVEN NAME	MIDDLE INITIAL OR NAME	FAMILY (OR LAST NAME)

Inventor's Signature _____

Date _____ Country of Citizenship _____

City of Residence _____

Post Office Address _____

Full name of ninth joint inventor, if any

_____	_____	_____
GIVEN NAME	MIDDLE INITIAL OR NAME	FAMILY (OR LAST NAME)

Inventor's Signature _____

Date _____ Country of Citizenship _____

City of Residence _____

Post Office Address _____

**ADDED PAGE TO DECLARATION FOR PATENT APPLICATION
FOR SIGNATURE BY ADMINISTRATOR(TRIX), EXECUTOR(TRIX)
OR LEGAL REPRESENTATIVE ON BEHALF OF DECEASED OR
INCAPACITATED INVENTOR (37 C.F.R. §§ 1.42 AND 1.43)**

I, Darlene Schuette, hereby declare that I am a citizen of the United States of America, residing at 9254 False River Road, New Roads, Louisiana, 70760, and that I am executing and signing the declaration to which this is attached as

(check one):

- ☐ the administrator(trix) of
☒ executor(trix) of the last will and testament of
☐ legal representative (of heirs) of

William L. Schuette, deceased, who was a citizen of the United States of America, residing in New Roads, Louisiana, with a post office address of 9254 False River Road, New Roads, Louisiana, 70760.

That, upon information and belief, I aver those facts that the inventor is required to state.

Date:

6-29-01

Darlene Schuette
Darlene Schuette

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